

# **Statistical Relationship between Variability of Sediment Sound Speed and Density**

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## **LONG-TERM GOALS**

Our long-term goal is to improve sonar performance through interpretation of geological data and high-frequency acoustic modeling. This work should improve understanding of the variability of the salient geoacoustic properties of the sea floor that control acoustic propagation and scattering.

## **OBJECTIVES**

Our objectives are to evaluate the statistical characterization of sediment sound speed and bulk density from experimental sites, describe statistically the nature of variability in these two parameters for several sediment types, and develop an accurate model that indicates the extent to which these two parameters are cross-correlated. We also expect to determine the optimal sampling approach for measuring sediment sound speed and bulk density as parameters predicting high-frequency scattering.

## **APPROACH**

Geological properties have been adequately sampled to address statistical accuracy, such that modeling of the natural variation based on sampled fluctuations is accurate and robust. Starting with a representative sound speed or bulk density power spectrum and correlation length estimated from existing data by K. Briggs, Monte Carlo realizations of the corresponding quantity would be estimated by D. Tang. A realization would be a three-dimensional simulation of the density variations in a core, based on an isotropic power spectrum with an exponential correlation function with a correlation length estimated from actual core data. From such realizations, we will re-apply the same procedures used in the actual core analysis on the simulated cores to obtain a “virtual” bulk density profile and then re-calculate the power spectrum. Because actual density is exactly known from the original data in the simulation, the difference between the parameters used in the simulation and the “virtual” parameters would be the distortion due to sampling effects. This procedure is applied to both density and sound speed simulations and repeated a statistically significant number of times to achieve robust estimates of “inferred” sound speed and bulk density spectra. Ultimately, we estimate the correlation coefficient between sound speed and density from these profiles. We intend to evaluate the number of

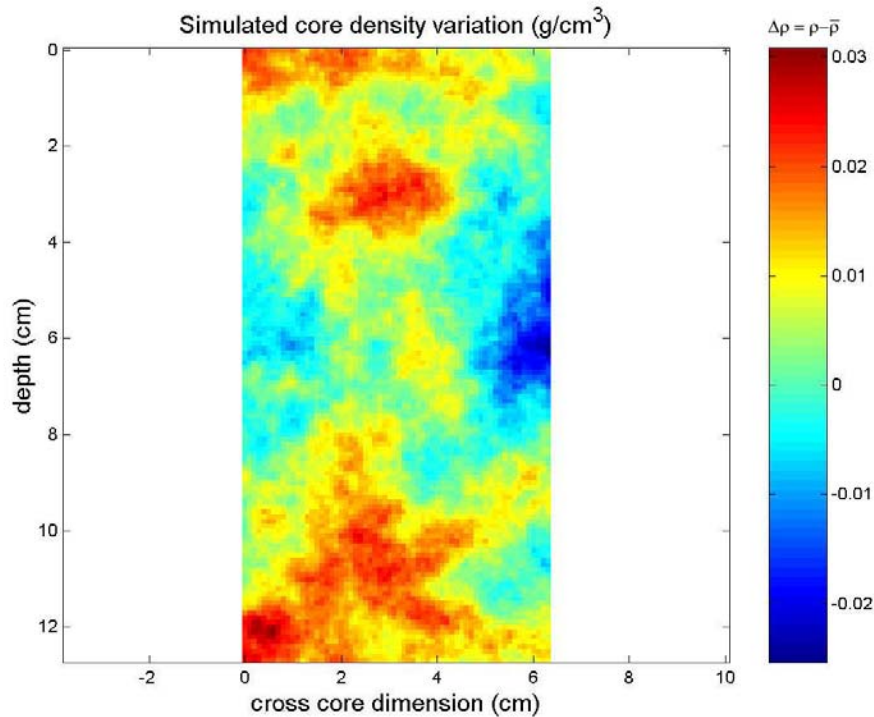
cores required for stable estimates of depth-dependent mean values and the spatial separation between consecutive measurements of each parameter in order to best estimate the cross correlation between sound speed and bulk density.

## WORK COMPLETED

We have modeled fluctuations in sediment sound speed and bulk density based from cores collected in a medium sand from the ONR-funded SAX99 High-Frequency Sound Interaction in Ocean Sediments experiment. Additionally, we have identified biases created in the core sampling for sediment bulk density and have estimated the cross correlation coefficient between sediment sound speed and bulk density from the SAX99 cores.

## RESULTS

The simulations were performed such that the deviations from the mean bulk density were rendered (Fig. 1). As a result of 18 simulations run to achieve a robust estimate of “virtual” bulk density, we showed that laboratory sampling procedures for assaying bulk density biased (lower) the actual variance of the density by averaging or smoothing. This result was evidenced by the estimation of longer correlation lengths from “sectioned” virtual cores than from the measured real cores. Besides the smoothing effect of using coarse sectioning intervals, the presence of mollusk shells could have an effect on the correlation length because the higher density shells affect the distribution of density. For example, the highest values of bulk density in a real core are restricted to discrete shell pieces, rather than distributed as continuous variations in the virtual core.



*Figure 1. An example of a simulation of a “virtual” core showing a two-dimensional slice through the three-dimensional simulation of  $\Delta\rho$ .*

When simulations of the sediment sound speed fluctuations were generated based on the density spectrum, but using the correlation lengths estimated from sound speed measurements on cores, the “virtual” cores were very similar in appearance to the ones depicting bulk density fluctuations. We found a positive cross correlation (0.3) between simulated values of sound speed and bulk density. Because there are different resolutions for sediment sound speed and bulk density, there are two interpretations for the measured cross correlation coefficient. Either the two parameters are partially correlated with a long correlation length, or totally correlated with a short correlation length.

## **IMPACT/APPLICATIONS**

Understanding and modeling the phenomena of propagation and scattering of high-frequency sound in the sea floor will aid in mine detection and classification for the navy.

## **RELATED PROJECTS**

The ONR-funded DRI “High-Frequency Sound Interaction in Ocean Sediments”, which continues as a planned Sediment Acoustics Experiment 2004 (SAX04). This experiment will provide geoacoustic data for generating simulations of sound speed and bulk density variability and opportunities for new sampling strategies based on the extant results. The investigation of measurement accuracy is also related to the ONR-funded “Statistical Analysis of Sediment Cores” project of Don Percival at APL-UW. Percival is determining the most accurate method of statistically describing the variability of these parameters in cores. Finally, the results will have relevance to any program that relies on acoustics as a tool to measure the sea floor such as the ONR Euro-Strataform and Mine Burial projects.

## **PUBLICATIONS**

- Briggs, K.B. and D. Tang. 2002. Assessing the sediment volume contribution to scattering: Bulk density fluctuations. In, *Oceans 2002 IEEE/MTS Proceedings*, Holland Publ., Escondido, CA, pp. 2093-2097. [published]
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